Mechanical nociceptive thresholds within the pastern region of Tennessee Walking Horses

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Summary

Reasons for performing study: 'Soring' is the term used to describe the application of an irritant to the distal forelimbs of gaited horses with the sole intent of inflicting pain and inducing altered gait, illegally practiced in Tennessee Walking Horses. Objective methods for the detection of limb pain due to this practice are, however, lacking.

Objectives: To assess whether Tennessee Walking Horses respond to manual pressures ≤ 10 kg/cm^2 and to establish reference mechanical nociceptive thresholds (MNTs) within the pastern region.

Methods: In 25 mature Tennessee Walking Horses in which no irritant had been applied, MNTs were evoked by a pressure algometer at 4 sites within the pastern region of each thoracic limb by 6 different examiners. The effects of age, sex, weight, height at withers, exercise and hand dominance of the examiners on MNTs were assessed. Correlations between the horse's perceived mental status, tolerance to the procedure and MNT values were also evaluated.

Results: Mechanical nociceptive thresholds ≤ 10 kg/cm^2 were observed in 20% of measurements, of which the mean ± s.d. MNT was 9.5 ± 0.3 kg/cm^2. Within 4 pastern sites, the palmar region had the lowest reference MNT value of 19.5 ± 3.6 kg/cm^2. Subject status, exercise, hand dominance, horse mental status and horse procedure tolerance did not significantly affect MNT values.

Conclusions: Reference MNTs of the pastern region of nontreated Tennessee Walking Horses provide an objective standard for the evaluation of those potentially applied irritant.

Potential relevance: Pressure algometry, *in lieu* of digital pressure, can quantify mechanical pressure applied during inspections to detect irritant therapy and provide consistency between examiners.

Introduction

The practice of inflicting pain on the limbs of a horse with the purpose of accentuating gait is known as 'soring' (Anon 2001). Irritating chemicals or mechanical devices may be applied to the distal limbs in an effort to produce a highly exaggerated gait of the fore and hindlimbs (i.e. 'big lick') that has become a highly desired trait in some Tennessee Walking Horses (Meszoly 2005). The practice was banned by the Horse Protection Act in 1970 because of concerns about nonhumane treatment (Anon 2001). Responsibility for enforcement of the Horse Protection Act is assigned to veterinary medical officers (VMOs) within the Animal and Plant Health Inspection Service (APHIS) of the US Department of Agriculture (USDA). Additional regulations established a Designated Qualified Persons (DQP) programme, which allow knowledgeable horsemen, such as veterinarians, farriers or trainers to be certified to inspect horses for the presence of soring.

The examination includes: a lameness examination; observation for any pain behaviour; physical examination of the forelimbs from the carpus distally; and inspection of the shoes, pads and action devices (i.e. chains) for regulation compliance (Anon 2005). The pastern region is examined visually for signs of inflammation, proliferative granulation tissue and open wounds. Digital palpation of the distal forelimbs is done in a systematic manner, with emphasis on identifying the presence of pain or abnormal tissue indicative of illegal therapy. During palpation, the thumb is applied with enough pressure to flatten the flesh of the thumb or partially blanch the thumbnail, which corresponds to approximately 2.3 kg of force (K. K. Haussler, unpublished data). Inspectors are trained to evaluate whether a positive pain response to digital palpation is repeatable and to ensure that the horse's reaction is not due to anxiety or excitement (Anon 2004).

One perceived limitation of the current examination is the inconsistent application of thumb pressure during digital palpation. Currently, applied digital pressure to the pastern region is not quantified and may differ between examiners. Many owners or trainers of horses that respond positively to the applied pressures often complain that too much pressure was applied or that any nontreated horse would react to the applied pressure. Pressure algometry applies quantifiable pressure and has been used to assess mechanical nociceptive thresholds (MNTs) within the axial skeleton and thoracic limb of normal horses (Haussler and Erb 2006; Haussler *et al.* 2007). Nonsored Tennessee Walking Horses were hypothesised to tolerate mechanical pressures ≤ 10 kg/cm^2 within the pastern region of the thoracic limbs.

Significant thermographic differences within the distal forelimb have been reported for treated and nontreated limbs within the same horse (van Hoogmoed *et al*. 2000). Diagnostic procedures, including ultrasonography or biomechanical evaluation of the distal limb, could potentially provide additional insights into detection; however, they are not practical for routine use at horse shows. The purpose of the current study was to assess whether nontreated Tennessee Walking Horses respond to manual pressures ≤ 10 kg/cm^2 as applied by experienced VMOs responsible for enforcement of the Horse Protection Act and to establish reference MNTs within the pastern region using pressure algometry.

Materials and methods

Horses

Mechanical nociceptive thresholds (MNTs) within the pastern region of the distal forelimbs were evaluated in 26 Tennessee Walking Horses. All were actively showing horses registered with the Tennessee Walking Horse Breeders' and Exhibitors' Association (TWHBEA) and housed on a single farm. The horses had been in active training for median of 3 years (range 1–10 years), and were flat-shod in the fore and unshod in the hind feet. Horses were restrained quietly by owners with a halter and loose lead rope during all procedures.

Participating horses were required to have no signs of lameness, during in-hand walking on a hard surface, and to pass a Horse Protection Act inspection for soring by 2 APHIS veterinary medical officers (VMOs) (L.B. and K.H.) with experience in Horse Protection Act enforcement for the USDA. Examinations and MNT measurements were performed by 5 examiners (L.B., K.H., S.K., J.P. and T.T.) chosen from the current ranks of VMOs participating in Horse Protection enforcement. All protocols were approved by the Animal Care and Use Committee at Colorado State University.

Horse Protection Act examination

Prior to MNT measurements, 2 VMOs selected at random observed the horses walking in a figure-eight pattern and digitally palpated the unweighted thoracic limbs from carpus to hoof, with particular emphasis on the pastern region. Any pain response or skin lesions and scarring were graded subjectively as mild, moderate or severe. The examiners applied light digital pressure (i.e. amplitude that initiated blanching of the thumb nail) to the palmar surface of the pastern region and the bulbs of the heel (Anon 2004). While continuing to support the unweighted limb, the VMOs extended the foot and leg of the horse cranially visually to inspect the dorsal, lateral and medial surfaces of the pastern region and coronary band for skin lesions, and to apply digital pressure in order to identify signs of pain or inflammation. Horses with any evidence of lameness or soreness were excluded from the study.

Algometry training session

The VMOs did not have any experience with pressure algometry and were therefore first trained in the technique and how to observe a typical adverse reaction with applied pressure. Guided by an experienced algometry user (K.K.H.), MNT measurements were taken by each VMO at several bony and soft tissue sites along the axial skeleton and within the forelimb pastern region in nonweightbearing limbs of a single horse, which was not included in final data collection.

Experimental procedure

MNTs were recorded at 4 pastern sites commonly found to be painful in treated horses (Table 1). The order of the MNT measurements, within each unweighted limb, was systematically randomised. The VMOs were assigned at random to measure MNTs at all 4 pastern sites within one or both thoracic limbs using previously described techniques (Haussler and Erb 2006) and one of 5 pressure algometers[1], with a calibrated range 0–10 kg/cm^2. The algometers were exchanged randomly between examiners and examinations in order to assess whether nontreated horses would respond to manual pressures ≤ 10 kg/cm^2 applied by experienced Horse Protection personnel, inexperienced with pressure algometry. To establish reference MNT values within the pastern region, one author (K.K.H.) conducted a final MNT measurement session of both thoracic limbs in all horses using a single pressure algometer[2] with a calibrated range 0–30 kg/cm^2. The higher pressure algometer was used last to limit any tissue trauma that could have interfered with subsequent MNT measurements.

Pressure was applied perpendicular to the predetermined anatomical sites at approximately 5–10 kg/cm^2/s over 2–3 s until a local avoidance reaction was noted or until the maximum recordable pressure of the gauge (i.e. >10 kg/cm^2 or >30 kg/cm^2) was applied. Avoidance reactions, included lifting the thoracic limb or pulling the limb away from the applied pressure. When a reaction was noted, the applied pressure was stopped immediately and the corresponding value recorded. The examiners did not view the MNT reading during the application of pressure to limit potential bias. Three consecutive measurements at 2–3 s intervals were recorded at each site to assess within-site repeatability. Approximately 2 min were allowed between examinations; because during an actual horse show or sale examination, no less than 2 min normally elapses between examinations done by different examiners. Due to the randomised study design, each horse was evaluated by 4 or 5 examiners for a total of 48 or 60 MNT measurements per thoracic limb. The measurement session for each horse lasted approximately 20 min and all measurements were done on a single day.

All examiners were right-handed. MNTs measured at medial or lateral pastern sites with left and right hands of the examiners

TABLE 1: Musculoskeletal landmarks used to assess MNT values within the pastern region of the thoracic limb

Pastern region	Anatomic location
Lateral	Lateral-most surface of the pastern region; 1 cm proximal to the coronary band; over the lateral collateral ligament of the pastern joint.
Dorsal	Dorsal surface of the pastern region; 1 cm proximal to the coronary band on the mid-sagittal plane; over the common digital extensor tendon.
Medial	Medial-most surface of the pastern region; 1 cm proximal to the coronary band; over the medial collateral ligament of the pastern joint.
Palmar	Palmar surface of the pastern region; level with the proximal edge of the lateral hoof cartilages on the mid-sagittal plane; over the deep digital flexor tendon.

were compared in an effort to assess the effect of hand dominance on recorded MNT values. To assess adaptation or sensitisation, 3 consecutive measurements at each site by each examiner were evaluated for sequential increases (i.e. adaptation), sequential decreases (i.e. sensitisation) or no change or consistent patterns. The proportions of the 3 patterns and the range of the 3 consecutive measurements were recorded. The median of the 3 measurements at each site were used as the site-specific baseline MNT for that horse.

For the 30 kg algometer data, the average range (across sites and horses) was interpreted as a measure of overall repeatability and left-to-right comparisons were made to determine whether bilateral MNTs could be pooled into a combined value for each site. The effects of age (<7 years; ≥7 years), sex, weight (<410 kg; ≥410 kg) and height at withers (<154 cm; ≥154 cm) on MNTs measured with the 30 kg algometer were assessed separately for each site. A proportion of the horses had ridden-exercise within an hour before the MNT measurements. Comparisons were made between the MNT values in the recently exercised vs. unexercised horses.

Mental status

A separate nonblinded examiner subjectively graded (on a 1–5 scale) the overall mental status of the horses during the MNT measurements by each examiner: *Grade 1* if the horse was very calm and stood completely quiet during all MNT measurements, and *Grade 5:* if the horse was extremely anxious and unmanageable. *Grades 2, 3* and *4* were intermediate gradations of increased anxiety. Calmer horses were hypothesised to have higher nociceptive thresholds than anxious horses.

Tolerance to procedure

The same nonblinded examiner subjectively graded (on a 1–5 scale) the overall willingness or tolerance of the horses to stand quietly on each thoracic limb during MNT measurements by each examiner: *Grade 1* if the horse stood completely quiet and readily tolerated all MNT measurements, and *Grade 5* for repeated lifting of the limb and inability to stand still on the thoracic limb for the majority of MNT measurements with intermediate gradations of decreased tolerance

Statistical analyses

Fifty percent of MNT variables were not normally distributed based on Komolgorov-Smirnov tests; therefore, nonparametric tests were used. Wilcoxon signed rank tests (2-tailed) were used to test all left-right paired limb differences, left-right tolerance scores, the effect of the order in which the MNT measurements were taken and the effect of hand dominance on MNT values.

Pastern site differences in MNTs were assessed by Kruskal-Wallis test. *Post hoc* comparisons of the individual means were assessed by a Wilcoxon rank-sum test with a downward adjustment of alpha to 0.0125 (i.e. 0.05/4 independent comparisons = 0.0125). The presence or absence of skin lesions within the pastern region were compared to MNT values ≤10 kg/cm^2 and >10 kg/cm^2 for the 5 VMO examiners by Chi-squared analysis. The effects of age, sex, weight and height at withers on MNTs and differences between prior ridden exercise vs. no exercise were assessed using Wilcoxon rank sum tests (2-tailed). Spearman's rank correlation test was used to assess correlations between MNTs and scores for the horse's mental status and the tolerance to the procedure. Significance for all tests was set at P≤0.05.

Results

Horses

One horse was excluded from the study due to the inability to stand still for MNT measurements by all examiners. The remaining 25 horses included 11 mares, 11 castrated and 3 intact males, median age 7 years (range 3–12 years), bodyweight 405 kg (range 341–490 kg) and height at withers 153 cm (range 144–166 cm). All horses passed the examinations for evidence of treatment ('soring'). Six (24%) horses had skin lesions or mild scarring at the pastern region, which were not indicative of treatment (Table 2). These sites did not have significantly lower MNT values, compared to paired sites with normal skin in the opposite pastern or compared to horses without skin lesions in the pastern region.

MNT values

For the 5 VMOs, MNTs >10 kg/cm^2 were reported in an average of 80% (i.e. 53% [70/132], 76% [104/136], 77% [101/132], 97% [128/132] and 98% [141/144]) of the MNT measurements recorded per limb. Conversely, MNTs ≤10 kg/cm^2 were observed in an average of 20% (range 2% [3/144] to 47% [62/132]) of measurements, of which the pooled mean ± s.d. MNT for the 5 VMOs was 9.5 ± 0.3 kg/cm^2 (range 6.4–10.0 kg/cm^2) and the mean coefficient of variation was 0.03 (range 0.00–0.07). For MNTs ≤10 kg/cm^2, the mean left-to-right difference within horse was 0.1 ± 0.2 kg/cm^2. Interexaminer repeatability and the proportion of the patterns of 3 consecutive MNT measurements taken by the VMOs could not be calculated because of the large number of MNTs >10 kg/cm^2 (i.e. ceiling effect of the instrument).

Using the 30 kg pressure algometer, there were no significant differences in the proportion of the patterns of 3 consecutive MNT measurements between the left-right sides. The 3 consecutive measurements sequentially increased in 17 ± 14%, sequentially decreased in 13 ± 12%, and had no change or consistent pattern in 70 ± 15% of measurements. The mean range of 3 consecutive

TABLE 2: Description and gradation of skin lesions and scarring within the pastern region of the thoracic limbs

Horse no.	Affected limb	Lesion grade	Pastern location	Lesion description
2	Left	Moderate	Mid-pastern, palmar surface	2 cm^2 scar
3	Right	Mild	Mediopalmar surface	1 cm^2 scaly lesion; mild hair loss
11	Right	Mild	Mediopalmar surface, above heel bulb	1 cm linear, scaly lesion
15	Right	Mild	Palmarolateral surface	1 cm^2 scar
21	Left	Mild	Palmar surface	1 cm^2 scar
24	Left	Mild	Palmar surface	2 cm long x 1 cm wide scar

measurements across horses was 2.1 ± 1.6 kg/cm^2. The mean left-right paired difference within horse was 0.7 ± 2.8 kg/cm^2, which was within the measurement error of the 30 kg algometer for 3 consecutive measurements. Despite limb randomisation, the left thoracic limb MNTs were notably lower than the paired right-sided MNTs for the 30 kg algometer, in the face of no significant left-right differences. The palmar region had the lowest pooled MNT values of the 4 pastern sites (Table 3). Age, sex, bodyweight, wither height, recent exercise, order of measurements did not significantly affect pastern MNT values measured by the 30 kg algometer. Hand dominance of the examiners did not significantly affect MNTs measured within the medial and lateral pastern sites.

Mean $\pm$ s.d. mental status grade was 1.3 ± 0.7 (range 1–5). Ten horses had at least one mental status score >1, across all 6 examiners. The distribution of mental scores during each examination was *Grade 1* (n = 120), *Grade 2* (n = 20), *Grade 3* (n = 6), *Grade 4* (n = 3), and *Grade 5* (n = 1), across horses. Horses with high initial mental status scores tended to have lower scores after repeat MNT examinations. Mental status grades did not correlate with MNT values, but were positively correlated with tolerance to the procedure scores within both thoracic limbs (r >0.74; P<0.001). The average tolerance to the procedure score was 1.3 ± 0.6 (range 1–4) for both left and right thoracic limbs. Thirteen horses had tolerance scores of 1 within both limbs for all 6 examiners. The distribution of tolerance scores for each limb was *Grade 1* (n = 162), *Grade 2* (n = 48), *Grade 3* (n = 8), and *Grade 4* (n = 1). There were no significant left-right differences in tolerance scores and no significant correlations between tolerance scores and MNT values.

Discussion

Treated ('sored') horses react strongly to the application of minimal pastern pressure, which is the primary mechanism for inducing the desired altered gait associated with most Tennessee Walking Horses. Historically, examination methods have included applying only enough manual pressure partially to blanch the thumbnail in order to elicit a pain response in treated tissue within the pastern region. Given that an applied force of approximately 2.3 kg is required to blanch the thumbnail and a

typical thumbprint surface area is 4–6 cm^2, the resulting applied pressure is 0.4–0.6 kg/cm^2. Owners and trainers, accused of showing illegally treated horses, often claim that the examining personnel are 'pressing too hard' on the pastern landmarks and inducing a false positive response. We do not know the typical MNT values or possible variation in nociceptive levels in 'sored' horses, since only nontreated horses were measured in this study. The current project demonstrated that in nontreated horses, examined by experienced VMOs, none of the horses responded to pressures less than 6.4 kg/cm^2 and that the majority of MNT measurements were >10 kg/cm^2. The single lowest MNT measurement recorded, 6.4 kg/cm^2, is between 11 and 16 times greater than the suggested pressure application defined within the current HPA training manual (Figure 1: Anon 2004). When the lowest reference MNT at the palmar pastern region was considered (i.e. 19.5 kg/cm^2), the threshold difference was 33–49 times greater than the HPA guidelines. The current study suggests that a more stringent pressure threshold of 5 kg/cm^2 or even 10 kg/cm^2 could be used to detect illegal treatment in Tennessee Walking Horses, with a low risk of false positive tests for examiners inexperienced in using pressure algometry.

No correlation was possible in this study between digital pressure applied to treated horses and MNT values since compliance with the HPA was required. A limitation of the current study was that all of the horses were flat-shod. It is likely that horses with long toes and shod with typical pads, weighted shoes and applied action devices (i.e. boots or chains) would have lower reference MNTs. Future studies need to measure MNTs in known illegally treated horses to determine the nociceptive threshold at which these horses react. Presumably, the MNT would be lower than 0.4–0.6 kg/cm^2, the current thresholds reported here. Our hypothesis was that nontreated horses would not respond to MNTs ≤10 kg/cm^2, which was true for the majority of measurements. The 10 kg/cm^2 ceiling of the pressure algometers used by the 5 VMOs was an experimental constraint used to prevent tissue injury and, consequently, the upper MNT limits at each site were often not attained by these 5 examiners. It is possible that MNT measurements made prior to the final reference measurement within each horses altered the final MNT values, although, no consistent trends were noted.

There is a learning curve associated with using the pressure algometer, as evidenced by the differences in MNTs measured between the VMOs and the first author (K.K.H.) (Antonaci *et al*. 1998). Between VMO examiners, there was general repeatability (i.e. horses with high MNTs and horses with low MNTs were noted by most examiners), even though one examiner consistently measured lower MNT values. Formal inter- and intraexaminer repeatability could not be calculated because of the ceiling effect of the instrument and because not every horse was measured by every examiner.
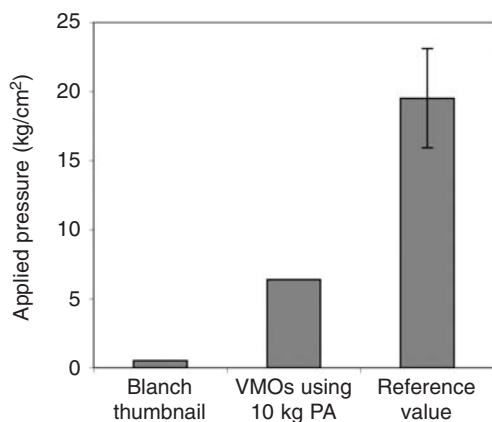

Fig 1: Comparison of applied pressures between that which is required to partially blanch the thumbnail, the lowest MNT measured by any of the 5 VMO examiners using a 10 kg upper limit pressure algometer (PA), and the lowest reference MNT (mean ± s.d.) of the pastern region in nonsored Tennessee Walking Horses (in kg/cm^2).

TABLE 3: Mean (± s.d.) pooled left-right MNT values of the pastern region in Tennessee Walking Horses (in kg/cm^2)

Pastern region	MNT
Lateral	27.6 ± 2.3^a
Dorsal	27.9 ± 2.6^a
Medial	27.5 ± 1.8^a
Palmar	19.5 ± 3.6^b

[a-b]Values with different superscript letters indicate significant (P<0.05) differences among pastern sites.

Further studies need to determine if pressure algometry is useful in detecting pain associated with naturally occurring skin lesions or scarring within the distal limb. In the current study, MNTs were not lower in the horses with skin lesions within the pastern region probably because of the mild grade of the superficial skin lesions. Studies on back and sacroiliac pain and induced carpal osteoarthritis suggest that pressure algometry is effective both for localising and quantifying pain (Haussler and Erb 2006; Varcoe-Cocks *et al*. 2006; Haussler *et al*. 2007). With pressure algometry, only the specific tissues and nociceptive fibres directly underneath the probe tip are measured. Areas of pain could have been present within the pastern region that were not measured with the instrument.

In an attempt to assess short-term adaptation and sensitisation to the procedure, 70% of the 3 consecutive measurements had no or consistent change within the pastern region, which was similar to values reported within the axial skeleton (68%) and the thoracic limb (72%) (Haussler and Erb 2006, 2007). As a measure of repeatability, the mean range of 3 consecutive measurements across horses in the current study (mean ± s.d. 2.1 ± 1.6 kg/cm^2) was similar to that reported for the thoracic limb (2.0 ± 1.4 kg/cm^2) (Haussler *et al*. 2007). MNTs at the pastern region are approximately 2–3 kg/cm^2 higher than those reported at the fetlock in a prior study on 24 mixed-breed range horses with limited handling or training experience (Haussler *et al*. 2007).

The higher MNTs at the pastern region may reflect true anatomical differences from the fetlock or may be associated with dissimilarities in the amount of prior handling and exercise between the 2 groups of horses or due to differences in methodology: MNTs were measured in nonweightbearing limbs in the current study, but in weightbearing limbs in the previous study. Theoretically, MNTs would be expected to be lower in nonweightbearing limbs because of the ease of producing an avoidance response, compared to a weightbearing thoracic limb.

Within the axial skeleton, higher MNTs occur in horses with ridden compared to nonridden treadmill exercise (Haussler and Erb 2006). The current study consisted of actively ridden horses; however, a proportion of the horses had ridden exercise immediately prior to MNT measurements. There were no significant effects of immediate exercise on MNTs in this group of horses, which is useful for future studies assessing the effects of exercise on treated or heavily shod horses. In the current study, MNT measurements were recorded only within a single body region, which may not have provided enough variability to detect age, sex, weight or height differences in MNTs, as reported in prior studies (Haussler and Erb 2006; Haussler *et al*. 2007). There were no significant differences in MNTs measured by the dominant or nondominant hands of the examiners, despite the application of a near maximal physical effort for the determination of most MNTs using the 30 kg algometer.

The effects of anxiety or fear on MNT values in horses have not been reported; horses displaying these behaviours would be expected to resist and not stand still for examination of their distal limbs or MNT measurements. In the current study, anxious horses did not have significantly lower MNTs, compared to calm horses, although one horse was excluded from the study because of its refusal to stand still for attempted MNT measurements. Anxious horses remained at the same mental score or became calmer during the repetitive MNT sessions. All MNT measurements were carried out in the horse's home environment and not at a novel or show setting where it is possible they might have lower and more variable MNTs and more difficulty in standing still for the procedure. The majority of horses tolerated the MNT procedure exceptionally well, similar to other studies (Haussler and Erb 2006; Haussler *et al*. 2007).

Pressure algometry has the potential to be used as an enforcement tool in Horse Protection as an objective measure of applied manual pressure and nociception within the pastern region of sored and nonsored Tennessee Walking Horses. The Fédération Équestre Internationale (FEI) Veterinary Regulations prohibit temporary or permanent limb desensitisation or hypersensitisation by any means (Anon 2006). Future studies need to establish baseline MNT values within the distal limbs of other breeds, as pressure algometry may prove also to be an objective enforcement tool in other disciplines.

Acknowledgements

Manufacturers' addresses

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Author contributions This study was conceived, initiated and planned by K.K.H. and T.H.B. Its execution was by K.K.H. and T.H.B., and statistics by K.K.H. and A.E.H. All authors contributed to the writing of the paper.